FactSheet

National Aeronautics and
Space Administration

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FS-2000-09-55-LaRC

Airborne UV Differential Absorption Lidar (DIAL): Measuring Ozone and Aerosols in the Atmosphere

The ozone hole, the greenhouse effect, and global warming are concerns at the center of people's interest about the atmosphere. What exactly is causing these atmospheric conditions? How are they changing? How serious are they?

One way to answer these questions is to understand the characteristics of the atmosphere's components, such as clouds, aerosols (suspended particles), and ozone (a colorless, gaseous form of oxygen). Scientists have used laser radar or lidar (light detection and ranging) since the 1960s to study atmospheric particles and clouds. A lidar is an instrument that uses short pulses of laser light to detect particles or gases in the atmosphere much like radar bounces radio waves off rain in clouds. A telescope collects and measures reflected laser radiation, leading to a map of the atmosphere's structure. Researchers can then determine the location, distribution, and nature of atmospheric particles and clouds and, under special circumstances, molecular species.

Different types of lidars measure different atmospheric properties. Scientists know that different molecules absorb light only at certain wavelengths. They can then tune laser pulses to different wavelengths to target the type of atmospheric gases they want to study. To measure ozone as well as aerosols, NASA Langley scientists use a specialized lidar called the airborne Ultraviolet (UV) Differential Absorption Lidar (DIAL). These researchers have used ground-based DIAL systems since the mid-1960s and airborne UV DIAL systems since the early 1980s.

What is the Airborne UV DIAL System?

The NASA Langley airborne UV DIAL system is a lidar instrument that sends pulses of laser radiation at different wavelengths into the atmosphere to measure ozone and also simultaneously measure aerosols and clouds. The laser beams are pointed both upwards and downwards out of the aircraft. The UV DIAL system uses five laser (or lidar) wavelengths in three different regions of the electromagnetic spectrum (Fig. 1): two in the UV region for ozone measurements, two in the visible region, and one in the near infrared (IR) region. IR and visible wavelengths both measure aerosols and clouds. Comparing these two wavelengths can reveal information about the size distribution of aerosols. The two UV wavelengths determine the profile of ozone by analyzing the absorption differences due to

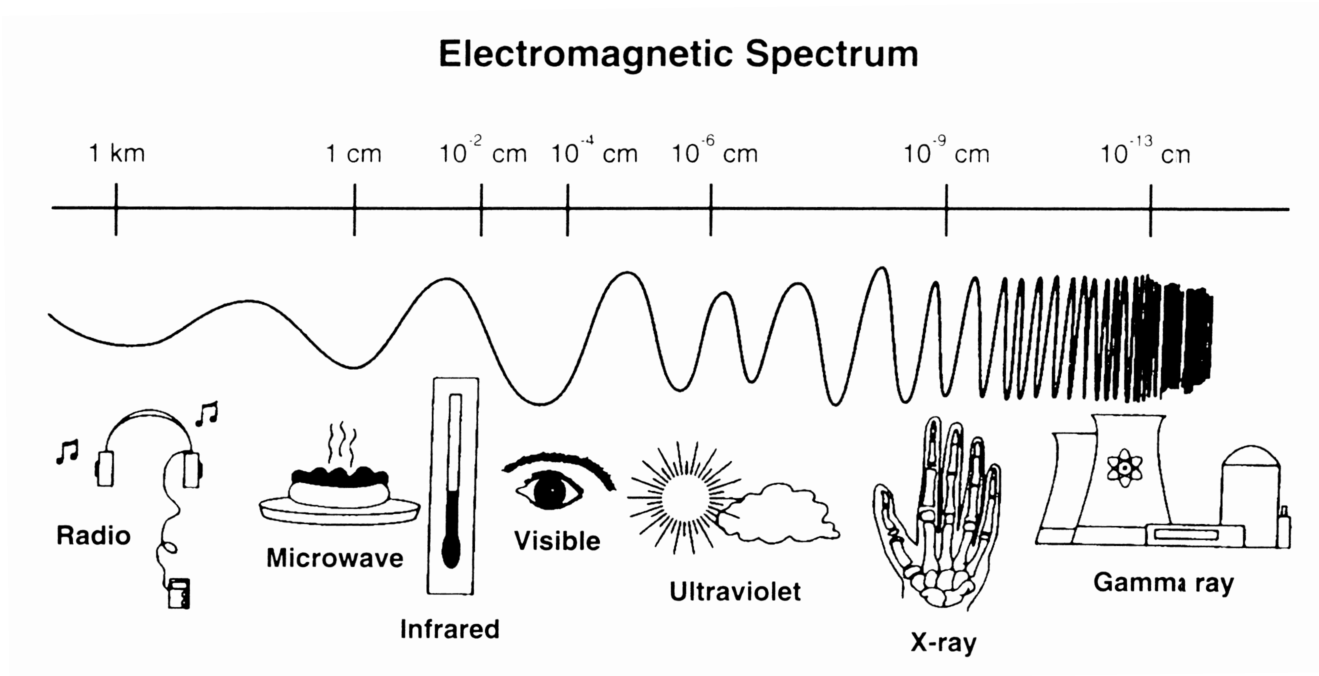

Fig. 1: The electromagnetic spectrum categorizes solar radiation from the longest to the shortest wavelengths.

ozone between the two lidar returns. From this measurement, scientists can determine the location and amount of aerosols, clouds, and ozone along the line-of-sight of the UV DIAL system.

Why measure ozone and aerosols?

Ozone and aerosols impact the daily lives of animals and plants on Earth. In the troposphere, ozone can damage human health and harm vegetation. In the stratosphere, however, ozone absorbs almost all of the UV radiation shorter than about $3x10^{-5}$ centimeters (cm)—one billionth of a meter—from the sun before it reaches the Earth's surface. UV-B radiation is the portion of the UV spectrum between $2.8x10^{-5}$–$3.2x10^{-5}$cm, which is near peak ozone absorption of $2.5x10^{-5}$cm. UV-B can cause melanoma and other skin cancers, cataracts, and immune deficiencies if stratospheric ozone does not absorb it. UV-B radiation, however, is also helpful. It assists in the production of vitamin D from cholesterol, which helps build strong bones and prevent rickets, many types of cancers, and multiple sclerosis.

Aerosols also affect the atmosphere in different ways. They can scatter sunlight into space, which cools the Earth, and also change the size of cloud particles, which affects when and how often it rains. Aerosols also have an important relationship to ozone. In the stratosphere, they can become sites for chemical reactions that convert chlorine from an inactive form to an active form that destroys ozone. Scientists also use aerosol distributions to trace atmospheric pollution. They can, for example, follow urban and industrial pollution or biomass burn plumes over oceans for thousands of miles away from their continental sources.

What are other uses for UV DIAL?

Airborne UV DIAL capabilities are also beneficial to other investigations aboard the aircraft. Scientists can gain a much broader understanding of the chemistry, composition, and nature of the atmosphere if they use UV DIAL to aid other instruments rather than if they used each instrument separately. Since UV DIAL takes measurements from above and below the aircraft, it creates an atmospheric map of the surrounding area (Fig. 2). Using this map, scientists can then locate other

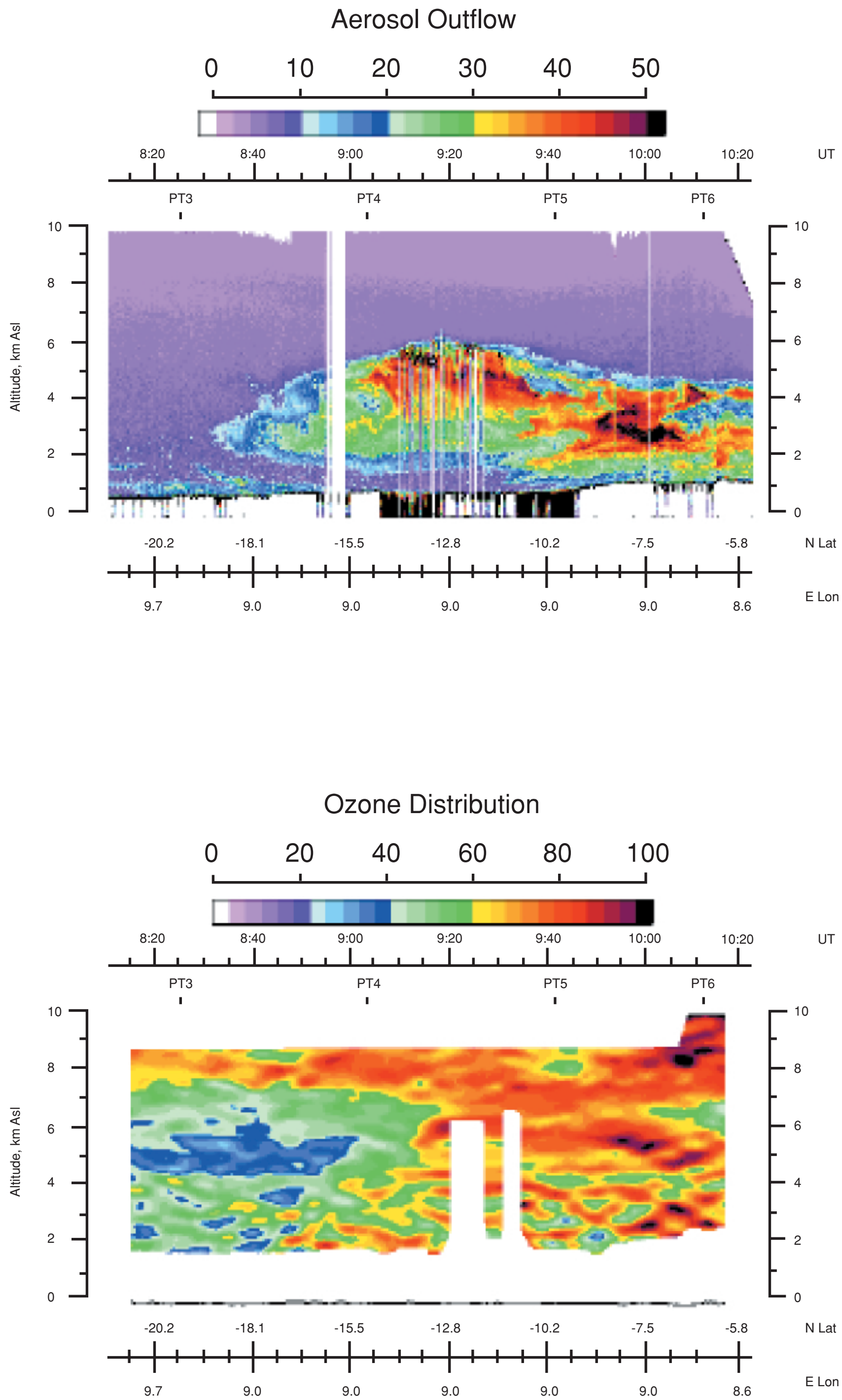

Fig. 2: Examples of atmospheric maps. The top image represents the outflow of aerosols associated with biomass burning in the western part of central Africa. The bottom image is a map of ozone distribution associated with the same burning plume from Africa (below 6 kilometers) and another outflow from Brazil (above 6 kilometers). The images were taken as the plane flew up the west central coast of Africa. The color scale from pink (low concentration) to black (high concentration) indicates the intensity of aerosol scattering and the concentration of ozone in the atmosphere. White areas indicate regions inaccessible to measurements because of a lack of data or clouds. For example, the white area below 1 km in the top image resulted because stratus clouds prevented the laser beam from measuring below them.

atmospheric events like a plume from a fire and navigate to the plume, allowing other instruments to study it.

Where do scientists use the Airborne UV DIAL System?

Troposphere

Scientists use the UV DIAL system to study ozone in both the troposphere (atmospheric layer that humans live in, which has an upper boundary of 8-18 kilometers, depending on location, above Earth's surface) and the stratosphere (layer above the troposphere with an upper boundary of 50 kilometers) (Fig. 3). In one six-week mission every year or two, scientists use the UV DIAL system to study the troposphere over remote areas such as the Atlantic and Pacific Oceans and parts of Africa, Brazil, and Canada. Researchers have studied topics such as the effects of biomass burning on the atmosphere and how pollution is transported over long distances.

Stratosphere

Every three to five years scientists use the UV DIAL system in an airborne field experiment to study ozone in the stratosphere, particularly in the polar regions where the most chemical ozone depletion occurs. Scientists have also used this system to study the effects that the eruption of Mount Pinatubo in the Philippines in 1991 had on reducing ozone in the tropical stratosphere. The UV DIAL system is also used to compare with ozone measurements made by other instruments, including those on satellites.

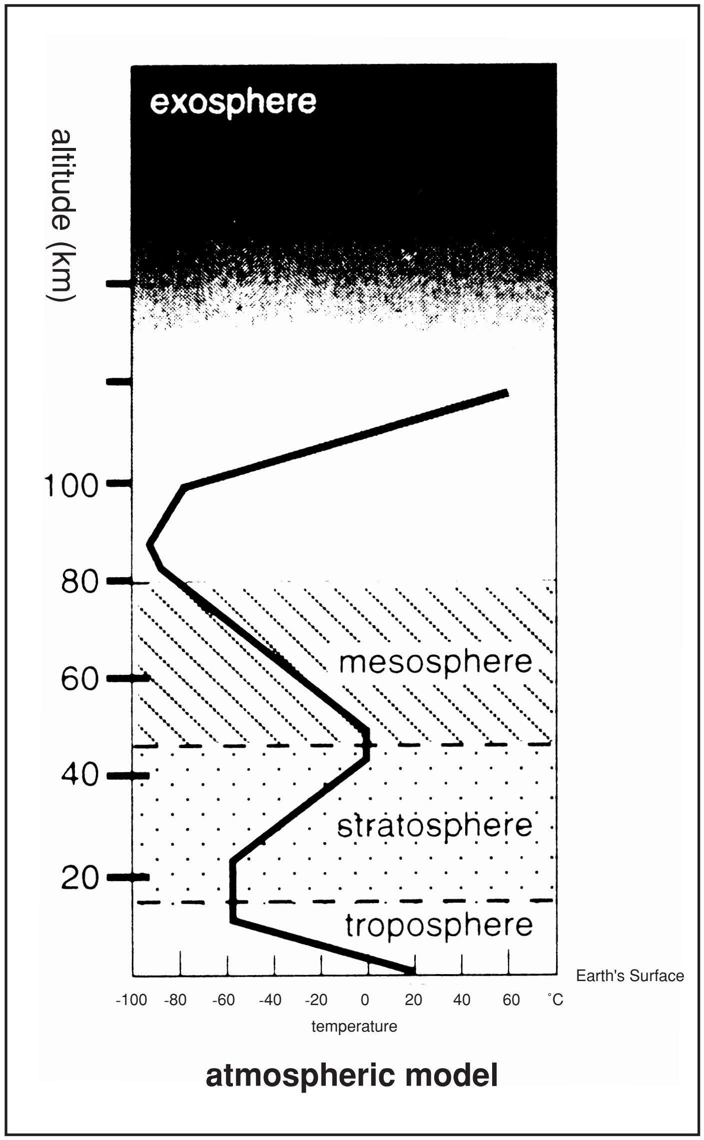

Fig. 3 A graphic illustrating the atmosphere's structure, starting with the troposphere at the Earth's surface.

For more UV DIAL information, please contact:
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Or see the Lidar Home Page at
http://asd-www.larc.nasa.gov/lidar/lidar.html
for additional information.